

- [54] URETHANES CONTAINING TWO PERFLUOROALKYLTHIO GROUPS
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Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 439,497, Feb. 4, 1974, Pat. No. 3,935,277.
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- [52] U.S. Cl. 560/25; 560/158; 560/164; 560/165; 560/162; 560/115; 260/268 R; 260/468 E; 260/482 B; 560/163; 560/26; 427/390 E; 428/424; 428/425
- [58] Field of Search 260/471 C, 482 B, 482 C, 260/468 E

[56] **References Cited**
U.S. PATENT DOCUMENTS

2,911,390	11/1959	Smith	260/77.5
3,413,271	11/1968	Weesner	260/77.5
3,547,894	12/1970	Smeltz	260/77.5
3,629,312	12/1971	Emerson et al.	260/482 B X
3,759,874	9/1973	Gresham	260/77.5 AP
3,906,049	9/1975	Hager et al.	260/471 C X
3,937,738	2/1976	Throckmorton	260/482 C X

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[57] **ABSTRACT**

Perfluoroalkylthio glycols and esters thereof can be prepared by the free-radical catalyzed addition of a perfluoroalkylthiol to an acetylenic alcohol or ester thereof. The compounds obtained are useful intermediates for the synthesis of fluorochemicals with low free surface energies having oil and water repellent properties. In one embodiment, a perfluoroalkylthio glycol can be reacted with a diisocyanate to obtain a polyurethane containing perfluoroalkylthio groups, which polyurethanes are useful as coatings to provide oil and water repellence to textiles and as additives to plastics to provide mold-release and other desirable properties.

9 Claims, No Drawings

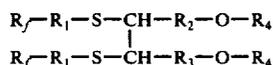
URETHANES CONTAINING TWO PERFLUOROALKYLTHIO GROUPS

This application is a continuation-in-part of application Ser. No. 439,497, filed Feb. 4, 1974, now U.S. Pat. No. 3,935,277, issued Jan. 27, 1976.

DESCRIPTION OF THE INVENTION

This invention relates to novel R_f -glycols and derivatives thereof which are useful as intermediates for the synthesis of fluorochemical compounds which possess low free surface energies and provide oil and water repellency. One aspect of this invention relates to a method of making said R_f -glycols esters and ethers. Another aspect of this invention relates to R_f -containing urethane compositions. One embodiment of this aspect of the invention relates to a reactive composition comprising a mono- or polyisocyanate or isocyanate terminated prepolymer and an R_f -glycol or hydroxyl-terminated R_f -containing prepolymer. In another embodiment of this aspect, the R_f -glycols can be converted to isocyanate-terminated R_f -prepolymers which form reactive compositions with alcohols, polyols, R_f -glycols, polyol prepolymers and hydroxyl-terminated R_f -containing prepolymers. In still another embodiment, the R_f -glycols can be used to replace part or all of the hydroxyl component in a urethane composition. In yet another embodiment, the invention relates to a urethane composition containing the residue of at least one R_f -glycol. Another aspect of the invention relates to a substrate containing 0.01 to 10% by weight of a fluorine-containing urethane composition, at least part of said fluorine being provided by one or more units derived from the R_f -glycols.

The novel R_f -glycols and derivatives thereof have the general formula:



where

R_f is straight or branched chain perfluoroalkyl of 1 to 18 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms,

R_1 is branched or straight chain alkylene of 1 to 12 carbon atoms, alkyleneethioalkylene of 2 to 12 carbon atoms, alkyleneoxyalkylene of 2 to 12 carbon atoms or alkyleneiminoalkylene of 2 to 12 carbon atoms where the nitrogen atom contains as a third substituent, hydrogen or alkyl of 1 to 6 carbon atoms,

R_2 and R_3 each independently is straight or branched chain alkylene of 1 to 12 carbon atoms or alkylene (polyoxyalkylene) of formula $C_mH_{2m}(OC_kH_{2k})_r$,

where

m is an integer from 1 to 12,

k is an integer from 2 to 6,

r is an integer from 1 to 40.

R_4 is hydrogen, alkyl of 1 to 24 carbon atoms or acyl where said acyl is derived from an aliphatic or aromatic carboxylic acid of up to 24 carbon atoms. Thus, R_4 can be hydrogen, alkyl of 1 to 24 carbon atoms, alkanoyl of 1 to 24 carbon atoms, alkenoyl of 1 to 24 carbon atoms or said alkanoyl or alkenoyl substituted by 1 to 3 of chloro, bromo and carboxyl, or said alkanoyl substituted by phenyl or naphthyl, said phenyl or naphthyl being unsubstituted or

substituted by 1 to 3 of chloro, bromo, alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 6 carbon atoms, or said alkanoyl substituted by lower acyl or lower acylamino where lower acyl means alkanoyl or alkenoyl of 2 to 6 carbon atoms and the mono- or di-chloro or bromo derivative thereof; or R_4 is benzoyl or benzoyl substituted by 1 to 3 of chloro, bromo, alkyl of 1 to 18 carbon atoms, alkoxy of 1 to 8 carbon atoms or lower acyl or acylamino where lower acyl means alkanoyl or alkenoyl of 2 to 6 carbon atoms, and the mono- or di-chloro or bromo derivative thereof.

Some preferred members of "lower acyl" are:

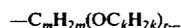
chloroacetyl, bromoacetyl, β -chloropropionyl, β -bromopropionyl, α,β -dichloropropionyl, α,β -dibromopropionyl, acryl, methacryl, α -chloroacryl, α -bromoacryl, α,β - or β,β -dichloro- or dibromoacryl, β -chlorocrotonyl, α -chlorocrotonyl, β -bromocrotonyl, and α -bromocrotonyl,

Useful compounds are those where

R_f is perfluoroalkyl of 6 to 12 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms,

R_1 is branched or straight chain alkylene of 2 to 8 carbon atoms, alkyleneethioalkylene of 2 to 8 carbon atoms, alkyleneoxyalkylene of 2 to 8 carbon atoms or alkyleneiminoalkylene of 2 to 8 carbon atoms where the nitrogen atom contains hydrogen or methyl as a third substituent;

R_2 and R_3 are each independently straight or branched chain alkylene of 1 to 4 carbon atoms or alkylene (polyoxyalkylene) of the formula



where

m is an integer from 1 to 4,

k is an integer from 2 to 4, and

r is an integer from 1 to 20, and

R_4 is hydrogen, alkyl of 1 to 24 carbon atoms, alkanoyl of 1 to 24 carbon atoms, alkanoyl of 1 to 6 carbon atoms substituted by phenyl, benzoyl, benzoyl substituted by alkyl of 1 to 6 carbon atoms, or R_4 is selected from chloroacetyl, bromoacetyl, β -chloropropionyl, β -bromopropionyl, α,β -dichloropropionyl, α,β -dibromopropionyl, acryl, methacryl, α -chloroacryl, α -bromoacryl, α,β - or β,β -dichloro or dibromoacryl, β -chlorocrotonyl, α -chlorocrotonyl, β -bromocrotonyl, or α -bromocrotonyl.

Particularly preferred are those compounds where

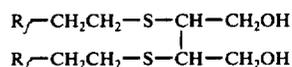
R_f is perfluoroalkyl of 6 to 12 carbon atoms,

R_1 is alkylene of 2 to 4 carbon atoms,

R_2 and R_3 are both alkylene of 1 or 2 carbon atoms, and

R_4 is hydrogen alkyl of 6 to 18 carbon atoms or alkanoyl of 6 to 18 carbon atoms.

One group of preferred compounds have the formula



where

R_f is perfluoroalkyl of 6 to 12 carbon atoms or

where

R_f is perfluoroalkoxyperfluoroalkyl of 4 to 12 carbon atoms, and especially

3

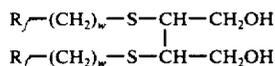
where

 R_7 is $(CF_3)_2CFO(CF_2CF_2)_y-$

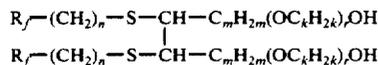
where

 y is an integer from 1 to 6.

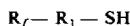
Another group of preferred compounds have the 5 formula



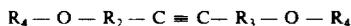
where

 R_7 is perfluoroalkyl of 6 to 12 carbon atoms and w is an integer from 1 to 8.A preferred group of alkylene (polyoxyalkylene)- 15 containing R_7 -glycols have the formula

where

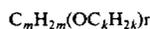
 R_7 is perfluoroalkyl of 6 to 12 carbon atoms, n is an integer from 1 to 12, m is an integer from 1 to 4, k is an integer from 2 to 4 and r is an integer from 1 to 20.The novel R_7 -glycols and esters described herein can 30 be obtained by the free-radical catalyzed addition reaction of a perfluoroalkylthiol of formula

to an acetylenic diol or ester of formula



where

4

 R_1 and R_4 are as previously defined. R_2 and R_3 each preferably is a straight or branched chain alkylene of 1 to 6 carbon atoms; said alkylene substituted by one or two of phenyl and cyclohexyl; or an alkylene (polyoxyalkylene) group of formula

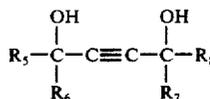
where

 m is an integer from 1 to 4, k is an integer from 2 to 4, r is an integer from 1 to 20,

and

 R_4 is preferably hydrogen.

In one embodiment, the acetylenic compounds have 15 the formula

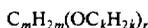


where

 R_5 , R_6 , R_7 and R_8 are selected from hydrogen, alkyl of 1 to 4 carbon atoms, cyclohexyl, and phenyl. 25Although R_2 and R_3 can contain such unsaturated groups as vinyl, allyl and styryl, such groups are not preferred since they compete for the R_7 -thiol and result in undesirable perfluoroalkyl by-products.In a particularly preferred embodiment, R_5 , R_6 , R_7 , and R_8 are each hydrogen or alkyl of 1 to 4 carbon atoms. Especially preferred is the case where R_5 , R_6 , R_7 , and R_8 are selected from hydrogen, and alkyl of 1 to 3 carbon atoms. 35In another preferred embodiment R_6 and R_7 are each hydrogen and R_5 and R_8 are selected from hydrogen, alkyl of 1 to 4 carbon atoms, cyclohexyl and phenyl.

Physical constants for some of the compounds described above are as follows:

Physical constants for some of the compounds described above are as follows:				
R_5	R_6	R_7	R_8	° C
H	H	H	H	MP 58°
CH ₃	H	H	CH ₃	BP 126-128° at 18mm
(CH ₃) ₂ CH	H	H	(CH ₃) ₂ CH	MP 69°
(CH ₃) ₂ CH-CH ₂	H	H	(CH ₃) ₂ CH-CH ₂	BP 158-160° at 15mm
C ₆ H ₁₃	H	H	C ₆ H ₁₃	BP 205° at 18mm
C ₆ H ₅	H	H	C ₆ H ₅	MP 12°
CH ₂ =CH-	H	H	CH ₂ =CH-	BP 146 at 15mm
CH ₃ -CH=CH-	H	H	CH ₃ -CH=CH-	MP 90-92°
C ₆ H ₅ -CH=CH-	H	H	C ₆ H ₅ -CH=CH-	MP 162°
CH ₃	CH ₃	CH ₃	CH ₃	MP 95°
C ₂ H ₅	CH ₃	CH ₃	C ₂ H ₅	BP 155-160° at 18mm
C ₂ H ₅	C ₂ H ₅	C ₂ H ₅	C ₂ H ₅	MP 74°
C ₃ H ₇	CH ₃	CH ₃	C ₃ H ₇	MP 56°-58°
C ₃ H ₇	C ₃ H ₇	C ₃ H ₇	C ₃ H ₇	MP 120°
C ₆ H ₅	CH ₃	CH ₃	C ₆ H ₅	MP 163°
C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	C ₆ H ₅	MP 193°

 R_2 and R_3 each is straight or branched chain alkylene of 1 to 12 carbon atoms; said alkylene substituted by one or two of phenyl, cyclohexyl; or an alkylene (polyoxyalkylene) group of formula

where

 m is an integer from 1 to 12, k is an integer from 2 to 6, r is an integer from 1 to 40,

Reference: "Acetylene Homologs and Derivatives" by Prof. Pierre Piganiol, Pages 295-300, Mapleton House Publishers, Brooklyn, N.Y., Copyright 1950.

60 R_7 -glycols where R_2 and R_3 are $C_mH_{2m}(OC_kH_{2k})_r$ can be made by converting the original acetylenic diol to the hydroxyalkyl ether, followed by free radical addition of the thiol $R_7R'-SH$. In like fashion the alkyl ethers, where R_4 is alkyl, can be prepared, using the 65 Williamson synthesis and known variations thereof.The R_7 -esters can be made by alternate routes. R_7 -glycols can be esterified by well-known synthetic organic methods, such as treatment of the alcohol with a

Compound	1 Hr. Half-Life Temperature ° C
2-t-butylazo-2-hydroperoxy-4-methylpentane	45° C
2-t-butylazo-2-cyano-4-methoxy-4-methylpentane	74° C
Di-t-butyl-4,4'-azobis-(4-cyano-peroxyvalerate)	80° C (azo)
azobisisobutyronitrile	81° C
2-t-butylazo-2-cyano-4-methylpentane	88° C
4-t-butylazo-4-cyanovaleric acid	93° C (trichloro-benzene)
1,3-dimethyl-3-(t-butylperoxy)-butyl-4-t-butylazo-4-cyanovalerate	94° C (azo)
t-butyl peroxy-4-t-butylazo-4-cyanovalerate	94° C (azo)
ethylene bis(4-t-butylazo-4-cyano-valerate)	94° C
2-(t-butylazo) isobutyronitrile	97° C
4-(4-t-butylazo-4-cyanovaleryloxy)-2-hydroxybenzophenane	100° C
2-t-butylazo-2-cyanobutane	104° C

Source: Commercial Development Department Lucidol Chemicals, Buffalo, N.Y.

Other azo-type free-radical catalysts are known and can be used but, because of their higher 1-hour half-life temperatures, are less preferred.

It is preferred to use an azo compound having a 1-hour half-life of from about 75° to about 90° C and a reaction temperature of from about 60° to about 80° C. Because of the ease of availability, it is preferred to use azo-bisisobutyronitrile as the catalyst.

The reaction can be carried out in bulk or in a suitable inert medium which acts to disperse or dissolve the reactants. The bulk reaction, without a solvent medium, is usually preferred. However, if solvents are used, useful solvents include ketones, such as acetone, methyl ethyl ketone and methylisobutyl ketone; esters such as ethyl acetate, butyl acetate, 2-ethylhexyl acetate; hydrocarbons such as hexane, heptane, octane and higher homologs, cyclohexane, benzene, toluene, xylene or blends of aliphatic, cycloaliphatic and aromatic hydrocarbons; alcohols such as ethanol, n-propanol, isopropanol, t-butanol and methyl cellosolve; ethers, both aliphatic and alicyclic including di-n-propyl ether, dibutyl ether and tetrahydrofuran. In addition, chlorinated solvents such as di-chloroethyl ether, ethylene dichloride, perchloroethylene and carbon tetrachloride can be employed.

Preferred solvents are the hydrocarbon solvents. Of the hydrocarbon solvents, the alkanes of 6 to 10 carbon atoms, the benzene hydrocarbons of 6 to 8 carbon atoms and mixtures thereof are preferred. Carbon tetrachloride and ethylene dichloride are useful chlorinated solvents. The data provided in Examples 17-29 indicates that yields are increased and by-product formation decreased when the alkane solvents are used. Commercially available mixtures of paraffinic, naphthenic and benzene hydrocarbon solvents can also be used successfully.

Using the reaction parameters described above, and continuing until reaction is complete, usually after 6 to 10 hours using azobisisobutyronitrile at 75° C, there can be effected an 85 to 95% conversion of the R_f-thiol to the desired R_f-glycol ether or ester. The overall yield can be increased to greater than 95% because unreacted R_f-thiol can be recovered and recycled. The R_f-glycols ethers and esters are generally insoluble in aliphatic and aromatic hydrocarbon solvents, while the R_f-thiols are soluble in these materials; the unreacted R_f-thiols are soluble in these materials; the unreacted

R_f-thiol can be readily recovered by washing the reaction product with a suitable hydrocarbon such as heptane or benzene. Alternately, the R_f-thiols can be recovered by passing the crude reaction product through a molecular distillation apparatus under conditions such that the R_f-glycols and esters pass through while the R_f-thiols are volatilized, and recovered.

As indicated above, the R_f glycols can be used to make R_f-containing urethane compositions. These urethane compositions have extremely low free surface energies and therefore, possess oil and water repellent properties, as well as mold release and other properties associated with low free surface energy. It should be noted that the urethane compositions of this invention are characterized by the presence of two perfluoroalkylthio groups on adjacent carbon atoms, a characteristic which provides improved oil and water repellent properties over the fluorinated urethane compositions of the prior art. Using the R_f-compounds and compositions described herein, it is possible to manufacture molds that display the excellent release properties characteristic of the silicone polymers.

In addition, the compounds where R₄ is C_mH_{2m}(OC_kH_{2k}), are useful as nonionic surfactants, especially where r is an integer from about 5 to about 30.

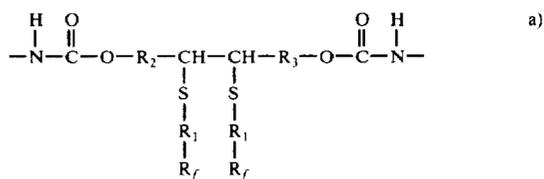
The esters, where R₄ is acyl and the ethers, where R₄ is alkyl are useful as additives to synthetic and natural polymers to reduce the surface energy and to provide mold release characteristics.

The diols, where R₄ is hydrogen can be used to make a variety of condensation products such as polyesters, polyamides, polycarbonates, polyurethanes and the like. The polyurethanes are particularly preferred.

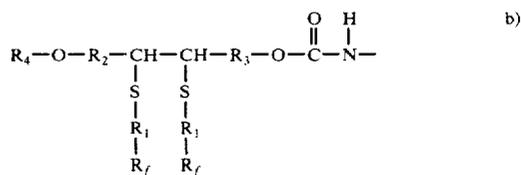
As used herein the term "urethane composition" means compounds and compositions which contain the characteristic



linkage and at least one R_f-containing group of formula



or



where

R_f, R₁, R₂, R₃ and R₄ are as previously described.

Preferred urethane compositions include those where R_f, R₁, R₂, R₃ and R₄ have the configurations previously described as being preferred.

The R_f-glycols can be used to make a wide variety of urethane intermediates and end products including

hydroxyl and isocyanate-terminated prepolymers, low molecular weight urethane compositions useful to render plastics soil repellent, and high molecular weight compositions useful as elastomers, foams, paints and varnishes, and textile treating compositions. It is also possible to modify these R_f -containing urethane compositions so that they are water soluble or self-emulsifiable, a property that is particularly useful in connection with the textile treating compositions.

Polyurethane elastomers generally have remarkable resistance to most solvents including gasoline, aliphatic hydrocarbons and, to some degree, aromatic hydrocarbons. They also exhibit excellent abrasion resistance. By inclusion of the R_f -glycol in an elastomer formulation, it is possible to increase the solvent resistance of urethane elastomers. The elastomers generally involve the reaction product of a diisocyanate, a linear long chain diol and a low molecular weight chain extender such as a glycol, diamine or polyol. Today, elastomers are generally prepared by a prepolymer technique whereby a diisocyanate is reacted with a hydroxyl-terminated polyester or polyether to form an isocyanate-terminated prepolymer. This prepolymer is then further reacted (chain extended) with a glycol, diamine or polyfunctional polyol (e.g. trimethylolpropane). Following the chain extension step, the liquid material solidifies and is removed from a mold and cured at elevated temperatures.

Urethane foams are usually prepared from diisocyanates and hydroxyl-terminated polyethers or polyesters. Linear or slightly branched polymers are used to provide flexible foams while more highly branched polymers produced rigid foams. Foaming is often accomplished by including water in the system, the reaction between isocyanate and water providing carbon dioxide for foaming. For rigid foams a low-boiling liquid such as trichlorofluoromethane has been used as a blowing agent.

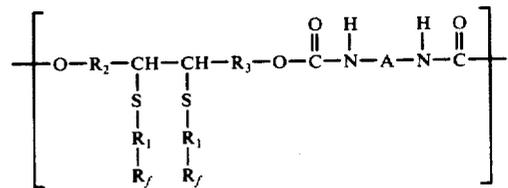
Appropriate selection of catalysts, stabilizers, surfactants and other additives controls the foam formation, cell size and type, density, cure and the like. By incorporating the R_f -glycol into urethane foams, especially molded foams, it is possible to achieve improved mold release properties in rigid, semi-rigid and flexible foams. It is also possible to improve the water and solvent resistance of foams used as insulation.

Incorporation of the R_f -glycols into polyurethane coatings such as paints and varnishes improves the water and solvent resistance thereof. Widely used systems include the two-component coatings wherein a non-volatile isocyanate derived from the reaction of tolylene diisocyanate with a polyol such as trimethylolpropane, is reacted with a polyfunctional polyester. Another system in use involves the one-component polyurethane coatings which are based on stable isocyanate-terminated prepolymers obtained from a diisocyanate such as tolylene diisocyanate and a polyfunctional polyether. Such coatings dry by the reaction of the free isocyanate groups with water or atmospheric moisture. The reaction proceeds through the unstable carbamic acid, with CO_2 being eliminated, to give primary amine groups which further react with isocyanate groups to form ureas.

Treatment of a textile with a fluorine-containing composition, notably a fluorine-containing polyurethane, provides oil and water-repellent characteristics thereto. Polyurethane compositions containing the residue of

the R_f -glycol display improved oil and water repellence on textile substrates.

Of the higher molecular weight urethane compositions, linear polymers, obtained by reacting an R_f -glycol with an organic diisocyanate, having recurring structural units of formula



where

R_f , R_1 , R_2 , and R_3 are as previously defined and A is a divalent organic radical, preferably alkylene of 2 to 16 carbon atoms, unsubstituted or substituted phenylene or naphthylene or unsubstituted or substituted biphenylene or bisphenylene are useful as plastics, fibers, coatings, and the like.

However, most urethane compositions that are used commercially to any great extent are copolymers that contain only a relatively small number of urethane linkages. These copolymers are prepared from a variety of segments, typically based on polyethers and polyesters and can have a molecular weight of from 200 to 10,000, generally from about 200 to about 4,000. By the inclusion of an appropriate amount of R_f -glycol in the starting materials, it is possible to prepare prepolymers that, when incorporated as part of a urethane composition favorably affect the properties thereof. It is similarly possible to incorporate a desired amount of R_f -glycol into the reaction mixture of a conventional prepolymer and an isocyanate so as to obtain conventional urethane compositions containing the divalent residue of the R_f -glycol. In the same way, there can be added an R_f -containing prepolymer together with or instead of the R_f -glycol.

The R_f -containing prepolymers can be hydroxy-terminated or isocyanate-terminated and, as indicated, can have a molecular weight as high as 10,000 although a molecular weight of 200 to about 4,000 is more usual.

Hydroxy-terminated prepolymers can be prepared by reacting an excess of a polyhydroxy component with a polyfunctional hydroxy-reactive component such as a polysiocyanate; an isocyanate-terminated prepolymer; a polybasic carboxylic acid, anhydride or acyl halide; phosgene; or a bischloroformate.

The polyhydroxy component can be a polyol, an R_f -glycol, a polyether, a polyester, an R_f -containing polyether, an R_f -containing polyester or mixture thereof.

The polyols are well-known in the urethane art and include

Ethylene glycol
1,3-propanediol
1,4-butanediol
1,5-pentanediol
1,6-hexanediol
1,9-nonanediol
1,10-decanediol
di-, tri-, tetra- and pentaethylene glycol
bis(4-hydroxybutyl) ether
bis(2-hydroxyethyl) thioether
bis(4-hydroxybutyl) thioether

1,4-bis(3-hydroxypropyl) benzene
 glycerol
 trimethylolpropane
 1,2,6-hexanetriol
 sorbitol
 mannitol
 pentaerythritol,
 2-ethyl-1,3-butylene glycol
 octamethylene glycol
 2-ethyl-1,3-hexanediol
 dodecamethylene glycol
 tetradecamethylene glycol
 hexadecamethylene glycol
 octadecamethylene glycol

The polyol can also contain cycloaliphatic groups, 15
 e.g. 1,4-cyclohexane-diol, 1,4-bis(hydroxymethyl) cyclohexane, 4,4'-dihydroxyl-1,1'-dicyclohexyl and the like. If desired, mixtures of polyols can be used.

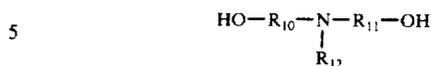
Polyols in addition to those described above, that are considered especially useful, are those containing tertiary nitrogen atoms which can be quaternized with acids, thereby converting a water-insoluble urethane composition into one that is water soluble or emulsifiable. Generally, an isocyanate-terminated prepolymer having a molecular weight of 200 to 10,000, preferably 400 to 4,000, is reacted with a difunctional tertiary amine to provide a segmented polymer containing tertiary nitrogen atoms. The nitrogen atoms can be quaternized, for example, by alkylation with methyl chloride or dimethyl sulfate to yield a composition that in polar media yields a dispersion in water. The polyammonium polyurethane compositions are obtained even more readily by neutralization of the basic polyurethane composition in a polar organic solvent such as acetone, methyl ethyl ketone, tetrahydrofuran, with a strong (HCl) or preferably weak ($pK > 4$) acid such as the $C_2 - C_9$ alkanic acids. Acetic acid is especially preferred because the acetic acid evaporates with the water on drying to leave the water-insoluble hydrophobic starting polyurethane composition.

The neutralized polyurethane composition in a polar solvent spontaneously forms a dispersion when water is stirred in. The solvent can thereafter be distilled off to give a solvent-free latex whose film-forming quantities are comparable to those of the organic solution.

In a convenient mode of preparing the water-dispersible basic polyurethane compositions, a polyester or polyether diol is reacted in a non-reactive polar solvent, such as acetone, methyl ethyl ketone, tetrahydrofuran and the like, with an excess of a diisocyanate such as tolylene diisocyanate or, preferably an aliphatic diisocyanate which tends to give non-yellowing urethanes such as dimer acid derived diisocyanate (DDI, commercially available from Quaker Oats Company) or another diisocyanate which is described herein as providing non-yellowing urethanes, and the prepolymer partially chain extended with an alkyl diethanolamine to yield a urethane composition containing tertiary amino groups. The urethane composition can then be acidified with a solution of aqueous weak acid ($pK > 4$) such as acetic acid; the concentration of acid is not critical. An emulsion immediately forms when this composition is added to water.

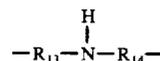
The polyurethane compositions can contain from as little as 5 to 800 milliequivalents of ammonium groups per 100 grams of polyurethane composition, preferably from about 50 to about 500 milliequivalents of ammonium groups per 100 grams.

Some useful polyols containing tertiary nitrogen atoms can be represented by the formula



where

10 R_{10} and R_{11} are alkyl of 2 to 4 carbon atoms or a group of formula



where

R_{13} and R_{14} are alkyl of 2 to 4 carbon atoms

R_{12} is alkyl of 1 to 18 carbon atoms, cyclohexyl, tolyl, xylyl, naphthyl, or with the nitrogen atoms forms piperazyl or pyridyl.

Useful polyols that contain tertiary nitrogen atoms include the alkoxyated aliphatic, cycloaliphatic aromatic and heterocyclic primary amines:

N-methyl-diethanolamine
 N-butyl-diethanolamine
 N-oleyl diethanolamine
 N-cyclohexyl-diethanolamine
 N-methyl-diisopropanolamine
 N-cyclohexyl-diisopropanolamine
 N,N-dihydroxyethylaniline
 N,N-dihydroxyethyl-m-toluidine
 N,N-dihydroxyethyl-p-toluidine
 N,N-dihydroxypropyl-naphthylamine
 N,N-tetrahydroxyethyl-aminopyridine
 dihydroxyethylpiperazine
 polyethoxylated butyldiethanolamine
 polypropoxylated methyldiethanolamine (molecular wt. 1000)
 polypropoxylated methyldiethanolamine (molecular wt. 2000)
 polyesters with tertiary amino groups
 tri-2-hydroxypropyl-(1)-amine
 N,N-di-n-(2:3-dihydroxypropyl)-aniline
 N,N'-dimethyl-N,N'-bis-hydroxyethylhydrazine
 N,N'-bis-hydroxypropylethylenediamine
 N,N'-dimethyl-N,N'-bis(hydroxyethyl)-ethylenediamine

11-stearlydiethanolamine
 N,N'-bis(hydroxyethyl)-piperazine

The R_f -glycols can be incorporated in the water-dispersible urethane compositions in an amount sufficient to provide the desired improvement in the surface properties of the polyurethane composition.

Useful polyethers are well-known and widely employed in urethane technology.

The polyethers are generally prepared commercially from lower alkylene oxides e.g. ethylene, propylene and butylene oxide and di- or polyfunctional alcohols. They have a molecular weight of from 400 to 5,000. A list of commercially available polyethers, trade names, molecular weight range and suppliers can be found in Volume 11, Polyurethane, page 511, Encyclopedia of Polymer Science and Technology, John Wiley and Sons, Inc., 1969.

Hydroxy-terminated polyesters can be prepared from a polybasic acid, anhydride or aryl halide and a polyol, a described above and/or an R_f -glycol.

Useful dicarboxylic acids are those derived from a saturated aliphatic dicarboxylic acid of 2 to 18 carbon atoms or an aromatic dicarboxylic acid of 8 to 18 carbon atoms, e.g. compounds of formula $B(\text{COOH})_2$ where B is preferably alkylene of 0-16 carbon atoms or arylene of 6 to 16 carbon atoms. Such acids include oxalic, malonic, succinic, glutanic, adipic, pirlnelic, suberic, azelaic, sebacic, brassylic, thopscic, octadecanedioic, 1,4-cyclohexanedicarboxylic, 4,4'-dicyclohexyl-1,1'-dicarboxylic, phthalic, isophthalic, terephthalic, methylphthalic, chlorophthalic, diphenyl-2,2'-dicarboxylic, diphenyl-4,4'-dicarboxylic, 1,4-naphthalene dicarboxylic, diphenylmethane-2,2'-dicarboxylic, diphenylmethane-3,3'-dicarboxylic, diphenylmethane-4,4'-dicarboxylic acid and the like.

Adipic acid and phthalic anhydride are the most common acid and anhydride. Of the polyols, the most commonly used include ethylene glycol, propylene glycol, 1,2-, 1,3- and 1,4-butylene glycol, 1,6-hexylene glycol, trimethylolpropane, glycerol 1,2,6-hexanetriol and diethylene glycol.

Useful hydroxyl-terminated polyesters can also be derived from natural castor oil and glycerol or from caprolactones and ethylene glycol. Such hydroxy-terminated polyesters have hydroxyl numbers ranging from 40 to 500 and very low acid numbers ranging from 0 to 2.

Hydroxyl-terminated polycarbonates can be obtained by reacting an excess of a polyol with phogene.

Hydroxy-terminated polybutadienes, or butadiene-styrenes and butadiene-acrylonitriles are useful herein, as are hydroxyl containing graft polymers of the polyether-polyacrylonitrile type.

Any convenient isocyanate can be used to react with the R_f -glycol or R_f -containing hydroxy-terminated prepolymer. Myriads of useful isocyanates are well-known in the art. Thus, one can use aromatic isocyanates, diisocyanates triisocyanates and polyisocyanates.

Useful aromatic diisocyanates can be represented by the formula



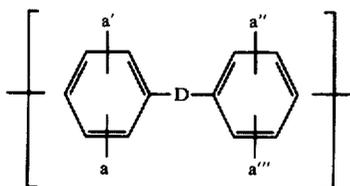
where

A is phenylene that is unsubstituted or substituted by one or two of alkyl of 1 to 4 carbon atoms, alkoxy of 1 to 4 carbon atoms, chloro, bromo and nitro.

naphthylene that is unsubstituted or substituted by one or two of alkyl of 1 to 4 carbon atoms, chloro, bromo and nitro

or where

A is a group of formula



where

D is a direct bond, oxygen, methylene or ethylene and

a, a', a'' and a''' each independently is hydrogen, alkyl of 1 to 4 carbon atoms alkoxy of 1 to 4 carbon atoms, chloro or bromo

Aromatic triisocyanates can be represented by the formula



where

B is the benzene or toluene group.

Aromatic di- and triisocyanates as described above include

Tolylene diisocyanate (TDI) (all isomers),
 4,4'-diphenylmethane diisocyanate (MDI)
 Tolidine diisocyanate
 Dianisidine diisocyanate
 m-Xylylene diisocyanate
 p-Phenylene diisocyanate
 m-Phenylene diisocyanate
 1-Chloro-2,4-phenylene diisocyanate
 3,3'-Dimethyl-4,4'-bisphenylene diisocyanate
 3,3'-Dimethoxy-4,4'-bisphenylene diisocyanate
 4,4'-Bis(2-methylisocyanatophenyl) methane
 4,4'-bisphenylene diisocyanate
 4,4'-Bis(2-methoxyisocyanatophenyl) methane
 1-nitro-phenyl-3,5-diisocyanate
 4,4'-diisocyanatodiphenyl ether
 3,3'-dichloro-4,4'-diisocyanatodiphenyl ether
 3,3'-dichloro-4,4'-diisocyanatodiphenyl methane
 4,4'-diisocyanatodibenzyl
 3,3'-dimethyl-4,4'-diisocyanatodiphenyl
 3,3'-dimethoxy-4,4'-diisocyanatodiphenyl
 2,2'-dimethyl-4,4'-diisocyanatodiphenyl
 2,2'-dichloro-5,5'-dimethoxy-4,4'-diisocyanatodiphenyl
 3,3'-dichloro-4,4'-diisocyanatodiphenyl
 benzene-1,2,4-triisocyanate
 benzene-1,3,5-triisocyanate
 benzene-1,2,3-triisocyanate
 toluene 2,4,6-triisocyanate
 toluene 2,3,4-triisocyanate
 1,2-naphthalene diisocyanate
 4-chloro-1,2-naphthalene diisocyanate
 4-methyl-1,2-naphthalene diisocyanate
 1,5-naphthalene diisocyanate
 1,6-naphthalene diisocyanate
 1,7-naphthalene diisocyanate
 1,8-naphthalene diisocyanate
 4-chloro-1,8-naphthalene diisocyanate
 2,3-naphthalene diisocyanate
 2,7-naphthalene diisocyanate
 1,8-dinitro-2,7-naphthalene diisocyanate
 1-methyl-2,4-naphthalene diisocyanate
 1-methyl-5,7-naphthalene diisocyanate
 6-methyl-1,3-naphthalene diisocyanate
 7-methyl-1,3-naphthalene diisocyanate
 polymethylene polyphenyl isocyanate and
 co-products of hexamethylene diisocyanate and
 tolylene diisocyanate

Useful aliphatic diisocyanates include those of general formula



where

A is alkylene of 2 to 16 carbon atoms.

Useful aliphatic polyisocyanates include

1,2-ethane diisocyanate
 1,3-propane diisocyanate
 1,4-butane diisocyanate
 2-chloropropane-1,3-diisocyanate

pentamethylene diisocyanate
 propylene-1,2-diisocyanate
 1,6-hexane diisocyanate
 1,8-octane diisocyanate
 1,10-decane diisocyanate
 1,12-dodecane diisocyanate
 1,16-hexadecane diisocyanate and
 other aliphatic diisocyanates such as
 1,3-cyclohexane diisocyanate
 1,4-cyclohexane diisocyanate
 cyclohexane triisocyanate
 4,4'-methylene bis(cyclohexyl) isocyanate

Additionally, the following diisocyanates are particularly preferred because urethane compositions made therefrom tend to be non-yellowing:

1,6-hexamethylenediisocyanate (HDI)
 2,2,4- and 2,4,4-trimethylhexamethylenediisocyanate (TMDI)

dimeracid derived diisocyanate (DDI) obtained from dimerized fatty acids, such as linoleic acid
 4,4'-dicyclohexylmethane diisocyanate (hydrogenated MDI)

isophorone diisocyanate

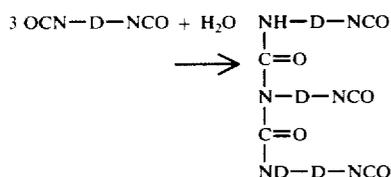
3-isocyanatomethyl-3,5,5-trimethylcyclohexylisocyanate

lysine methyl ester diisocyanate (LDIM)

bis(2-isocyanatoethyl) fumarate (FDI)

bis(2-isocyanatoethyl) carbonate

Other useful isocyanates include polyisocyanates, particularly triisocyanates which are readily obtained by the reaction of an excess of the corresponding diisocyanate with water according to the following equation:



where

D is the residue of a diisocyanate as described above; additional polyisocyanates include polymethylene polyphenylisocyanate (PAPI) and tris(isocyanatophenyl) thiophosphate (Desmodur R_f).

Additional isocyanate components can be prepared by reacting an excess of a diisocyanate as described above with a suitable hydroxyl component, such as a polyol as described above or an R_f -glycol as described herein, or combination thereof, to obtain an isocyanate-terminated prepolymer.

In addition to the polyisocyanates, useful urethane compositions can be obtained from the aliphatic and aromatic monoisocyanates. The low molecular weight urethane compositions obtained by reacting an R_f -glycol with a monoisocyanate are useful to impart soil and mold-release properties to a variety of natural and synthetic polymers.

Some useful aromatic monoisocyanates include

2-fluorophenyl isocyanate

3-fluorophenyl isocyanate

4-fluorophenyl isocyanate

m-fluorosulfonylphenyl isocyanate

trans-2-phenylcyclopropyl isocyanate

m-tolyl isocyanate

p-tolyl isocyanate

α,α,α -trifluoro-o-tolyl isocyanate

α,α,α -trifluoro-m-tolyl isocyanate

5 p-bromophenyl isocyanate

2,5-dimethylphenyl isocyanate

o-ethoxyphenyl isocyanate

p-ethoxyphenyl isocyanate

10 o-methoxyphenyl isocyanate

m-methoxyphenyl isocyanate

p-methoxyphenyl isocyanate

1-naphthyl isocyanate

o-nitrophenyl isocyanate

15 m-nitrophenyl isocyanate

p-nitrophenyl isocyanate

p-phenylazophenyl isocyanate

o-tolyl isocyanate

20 Useful aliphatic monoisocyanates include such alkyl isocyanates of 1 to 16 carbon atoms as

methyl isocyanate

ethyl isocyanate

n-propyl isocyanate

25 n-butyl isocyanate

t-butyl isocyanate

hexyl isocyanate

octyl isocyanate

30 dodecyl isocyanate

octadecyl isocyanate

hexadecyl isocyanate

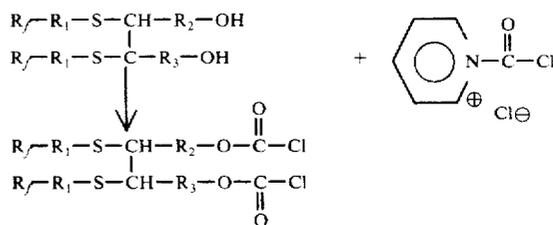
and mixtures thereof, as well as cyclohexyl isocyanate.

35 Isocyanate-terminated prepolymers typically having a molecular weight of from 200 to about 4,000 can be prepared by reacting an excess of an isocyanate component with a polyhydroxy component. The isocyanate component can be a diisocyanate or polyisocyanate as previously described, or can be a low molecular weight isocyanate-terminated prepolymer.

40 The hydroxy component can be one or more of a polyol, polyester, polyether, polycarbonate and R_f -glycol, all as described previously.

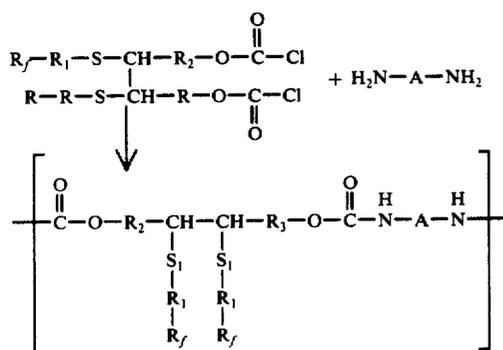
It can be seen that the properties of ultimate urethane compositions can be modified by appropriate modifications in the compositions of the prepolymers.

In addition to the formation of the urethane compositions described above, the R_f -glycols described herein can be converted to the corresponding bischloroformate by treatment with chlorocarbonyl pyridinium chloride:



65

which in turn can be reacted with an appropriate amine to yield a urethane composition:



where

A is a divalent organic radical as previously described.

The reaction between the isocyanate component and the hydroxyl component can be carried out in bulk, i.e., without solvent, or in the presence of non-reactive, anhydrous, organic solvents. Solvent media in which the reaction can be carried out include ketones, such as acetone, methyl ether ketone and methylisobutyl ketone; esters such as ethyl acetate, butylacetate, 2-ethylhexyl acetate; hydrocarbons such as hexane, heptane, octane and higher homologs, cyclohexane, benzene, toluene, xylene or blends of aliphatic, cycloaliphatic and aromatic hydrocarbons. It is also possible to employ ethers, both aliphatic and alicyclic including di-n-propyl ether, di-butyl ether, tetrahydrofuran and the diethers of polyalkylene oxides. In addition, chlorinated solvents such as dichloroethyl ether, ethylene dichloride, perchloroethylene and carbon tetrachloride can be used.

Among the solvents listed, the water miscible solvents such as acetone and methyl ethyl ketone are most important since they allow conversion of R_f -urethanes into water soluble R_f -urethanes as previously described.

In all cases, the solvents should be anhydrous to avoid urea formation.

The reaction can, if desired, be catalyzed and those catalysts conventionally employed in the urethane art are useful herein. Useful catalysts fall principally in two groups

a. amino compounds and other bases:

triethylamine and other trialkylamines triethylenediamine
 1,4-diaza-2,2,2-bicyclooctane
 N-(lower) alkyl morpholines
 N,N,N',N'-tetra-methylethelenediamine
 N,N,N',N'-tetramethyl-1,3-butanediamine
 N,N'-substituted piperazines
 dialkylalkanolamines
 benzyltrimethylammonium chloride

b. organometallic and inorganic compounds:

cobalt naphthenate
 stannous chloride
 stannous actoate
 stannous oleate
 dimethyl tin dichloride
 di-n-butyltin dilaurylmercaptide
 tetra-n-butyl tin
 trimethyl-tin hydroxide
 di-n-butyltindilaurate

Such catalysts may be used singly or in combination with each other. Beneficial synergistic catalysis may occur when combinations are used.

While it is possible to carry out the reaction without the use of a catalyst, it is preferable for reasons of economy and to assure a complete reaction, to utilize one or more catalysts as listed in amounts ranging from 0.001 to 1% based on the weight of the reactants. It is similarly advantageous to carry out the urethane synthesis at elevated temperature, usually between room temperature and 120° C and preferably at 60° to 80° C to obtain a complete reaction between 0.5 to 8 hours reaction time.

The reaction can be easily followed by titration of the isocyanate group or by IR analysis.

The determination of the critical surface tension (γ_c) in dynes per centimeter shows that the free surface energy of a polyurethane is lowered if the novel R_f -glycols are incorporated into the urethane chain.

The critical surface tensions (γ_c) are determined by contact angle measurements as described by W. Zisman, Contact Angles, Advances in Chemistry, No. 43, ACS Publications, Washington, D.C., 1964.

The usefulness of the polyurethane compositions is, however, conveniently shown by measuring the oil, water and soil repellency ratings of substrates such as fabrics, paper, leather, etc. which are treated with solutions or emulsions of the novel urethane compositions.

As already indicated, the urethane compositions of the invention are highly effective for imparting oil and water repellent properties to substrates to which they are applied and coatings of these polymers may be prepared by any of the well-known techniques. When prepared by bulk or suspension polymerization techniques, these urethane compositions can be applied, for example, from a dilute solution in suitable a solvent such as the fluoroalkanes, fluorochloroalkanes, fluoroalkyl substituted aromatics, alkylesters of perfluoroalkanoic acids, chlorinated alkanes or aromatics, hydrocarbon aromatics, ketones, esters and others. Concentrations of the fluorinated polymer in the solvent can be adjusted to provide an amount of urethane composition deposited on the substrate sufficient to provide oil and water repellency. This amounts typically to a deposit of from 0.01 to 10%, preferably from 0.1 to 1%, of urethane composition, based on the weight of substrate. If the urethane composition is obtained as an aqueous latex or emulsion, the system can be diluted with water or other appropriate diluent to similarly provide an amount of urethane ranging from 0.01 to 10% of the weight of substrate deposited thereon.

The urethane solution or latex may be applied by any of the known techniques such as by dipping, spraying, brushing, padding, roll coating or by any desired combination of such techniques. The optimum method of application will depend principally on the type of substrate being coated.

Coatings of the urethane compositions of the invention may be applied to any desired substrate, porous or non-porous. They are particularly suited for application to porous materials such as textiles, leather, paper, wood, masonry, unglazed porcelain and the like to provide valuable oil and water repellency properties. However, they may also be applied to non-porous materials such as metals, plastics, glass, painted surfaces and the like to provide similar oil and water repellency properties. More specifically the urethane compositions of the invention act as levelling, wetting and spreading agents

in formulations designed for application to floors, furniture and automobiles. In such applications a protective oil and water repellent film is left on the treated object after the removal of the bulk of the material. Such leveling, wetting, spreading and film forming properties are also useful in

- a. formulations for cleaning glass and other hard, non-porous materials
- b. hair care products such as rinses, shampoos and hair sprays
- c. paint, stain and varnish formulations for application to wood, masonry and ceramics.

In the treatment of paper the urethane compositions may be present as an ingredient in a wax, starch, casein, elastomer, or wet strength resin formulation. Aqueous emulsions of the urethane compositions are especially useful in the treatment of paper. By mixing the urethane compositions in an aqueous or oil type paint formulation, it may be applied effectively to unpainted asbestos siding, wood, metal and masonry. In the treatment of floors and tile surfaces and like substrates, and urethane compositions may be applied by their incorporation in an emulsion or solution.

Because of the ability of the surfaces treated with these urethane compositions to withstand abrasive action, the advantages incident to the repellency to oil and water and their resistance to soiling imparted by coating them with the urethane compositions of this invention, preferred classes of articles to be treated are papers and textiles.

Illustrative papers are carbonizing tissue, wallpaper, asphalt laminates, liner board, cardboard and papers derived from synthetic fibers.

For application to textile materials such as fabrics woven and non-woven, fibers, films, yarns, cut staple, thread etc. or articles made from fabrics, fibers, films, yarns, etc. the urethane compositions of the invention are preferably prepared as aqueous latices or emulsions which are then diluted, preferably with water and applied to the textiles from pad baths which may contain other treating materials. In accordance with this technique, the fabric or the textile material is passed through the bath, passed through squeeze rolls adjusted to leave the desired amount of the latex on the fabric, dried at a temperature of about 25° to 125° C and then cured in a curing oven at a temperature in the range of from 120° to 195° C for 0.2 to 20 minutes. The weight of urethane composition deposited on the fabric may range from 0.01 to 10% of the weight of fabric. Preferably, very small amounts are used in the range of 0.1 to 1%, often from 0.1 to 0.5% to give high degrees of water and oil repellency. Any types of textile materials, such as cotton, wool, fiber glass, silk, regenerated cellulose, cellulose esters, cellulose ethers, polyesters, polyamides, polyolefins, polyacrylonitrile, polyacrylic esters, inorganic fibers, etc. either alone or blended in any combination may be successfully coated with the urethane compositions of the invention. The resulting textile material will be found to be repellent to water and oil, and the textile material will retain its resistance to such agents even after many launderings and dry cleanings.

It will be often advantageous to use the urethane compositions of the invention in combination with conventional finishes, such as mildew preventatives, moth resisting agents, crease resistant resins, lubricants, softeners, fat liquors, sizes, flame retardants, antistatic agents, dye fixatives and water repellents.

The invention described above is illustrated by the following examples:

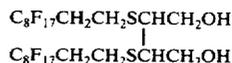
Examples 1 to 46 illustrate the preparation of the R_f-glycols and esters.

Examples 47 to 63 illustrate the preparation of urethane compositions and the present, practical utility of such compositions.

Examples 64 and 65 illustrate the preparation of the R_f-thiols.

EXAMPLE 1

2,3-Bis(1,1,2,2-Tetrahydroperfluorodecylthio)-butane-1,4-diol



2-Butyn-1,4-diol (1.1g; 0.013 mole) and 1,1,2,2-tetrahydroperfluorodecanethiol (13.64g; 0.028 mole) were stirred together in 16 ml 2-butanone with 0.4g azobisisobutyronitrile (ABN) catalyst. The solution was heated to 83° - 85° for four hours, then a further 0.4g of catalyst was added and heating and stirring were continued for a total of 24 hours. After cooling, the solvent was removed by evaporation and the product was recrystallized from benzene to give 8.28g of the desired product (61% conversion). Further purification was effected by distillation of the material (b.p. 180° - 204° at 0.6mm Hg) and final recrystallization from benzene. The pure product melted at 110° - 112°. The infrared spectrum showed OH stretching frequency at 3370 cm⁻¹; CH stretching frequency at 2938 and 2878 cm⁻¹ and CF stretching frequency from 1,330 to 1,100 cm⁻¹.

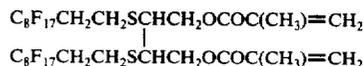
The structure was confirmed by nmr examination, which showed signals at:

2.0 - 3.4 ppm, —CH₂CH₂S— and OH (10H);
3.8 ppm, OCH₂ (4H); and 4.3 ppm, SCH(2H).

Analysis for C₂₄H₁₆F₃₄O₂S₂ Calculated: C, 27.55; H, 1.54; F, 61.73 Found: C, 27.54; H, 1.67; F, 61.46

EXAMPLE 1a

2,3-Bis(1,1,2,2-Tetrahydroperfluorodecylthio)butyl-1,4-Dimethacrylate



A 50 ml flask was charged with 2,3-Bis(1,1,2,2-tetrahydroperfluorodecylthio) butane-1,4-diol (10.46 g; 0.01 mole), pyridine (1.58 g; 0.02 mole) and a mixture of 15 ml heptane and 10 ml methylethyl ketone. The solid diol was dissolved with warming to 70° and continuous stirring. Methacrylyl chloride (2.00 g; 0.02 mole) was added over a 30 minute period, under nitrogen. A white solid gradually precipitated from the liquor. To ensure complete reaction the mixture was stirred at 70° for 8 hours. All solids were removed by filtration and the solvents were stripped under reduced pressure. Purification of the crude dimethacrylate on neutral alumina gave 7.2 g product (61.1% of theory) as a white, waxy solid.

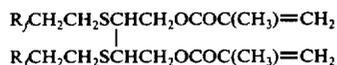
The structure was confirmed by spectroscopic examination. Infrared bands were observed at 1735cm⁻¹ (C=O stretching frequency) and 1637cm⁻¹ (C=C stretching frequency). Nmr showed peaks at 1.9 ppm (6H) CH₃; 2.0-3.3 ppm (10H) C₈F₁₇CH₂CH₂SCH; 4.35

ppm (4H) OCH₂; 5.58 ppm (2H) H trans to C=O; 6.1 ppm (2H) H cis to C=O. Nmr and GLC examination also showed the presence of a small amount of unreacted starting diol, which was difficult to remove. For this reason no true elemental analyses could be obtained.

On standing the monomer spontaneously polymerized to a brittle solid.

EXAMPLE 1b

2,3-Bis(1,1,2,2-Tetrahydroperfluoroalkylthio)butyl-1,4-Dimethacrylate

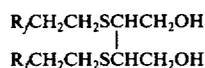


R_f = mixture of C₆F₁₃; C₈F₁₇; C₁₀F₂₁

2,3-bis(1,1,2,2-tetrahydroperfluoroalkylthio)butane-1,4-diol (40 g; 0.038 mole) was converted to its dimethacrylate by treatment with methacrylyl chloride (8.5 g; 0.082 mole) and pyridine (6.5 g; 0.082 mole) in heptane/methyl ethyl ketone solvent at 70° for 8 hours. Isolation and purification of the product gave 29 g mixed dimethacrylate, as an off-white waxy solid. The structure was confirmed by infrared and nmr spectroscopy. Infrared showed stretching frequencies at 1735cm⁻¹ (C=O) and 1638cm⁻¹ (C=C). Nmr signals were at 1.9 ppm (6H) CH₃; 2.0-3.34 ppm (10H) CH₂; 4.35 ppm (4H) OCH₂; 5.59 ppm (2H) H trans to C=O; 6.12 ppm (2H) H cis to C=O.

EXAMPLE 2

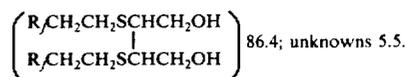
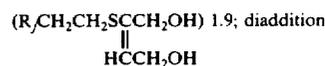
2,3-Bis(1,1,2,2-Tetrahydroperfluoroalkylthio)-butane-1,4-diol



a. Solvent Free Process

In a 500 ml Morton flask, 400g (0.8 mole) 1,1,2,2-tetrahydroperfluoroalkanethiol (similar to that described in Example 3, but having an average molecular weight of 500) was mixed with 327g (0.38 mole) 2-butyn-1,4-diol. With moderate stirring the flask was heated to 75° under nitrogen by means of an external oil bath. Azobis-

reaction product was (area %) thiol (R_fCH₂CH₂SH) 6.2; mono addition product



The crude product was purified by passage through a falling film molecular distillation apparatus at 110° and 8mm Hg. giving 325g. (85.0% conversion) product consisting of 1.2% thiol, 1.5% monoddiaddition product, 93.0% diaddition product and 4.3% unknowns. Recovery of unreacted thiol was 34g, bringing the overall yield (conversion and recovery) to 93.5%.

b. Solvent Process

In a 2 liter Morton flask 1,1,2,2-tetrahydroperfluoroalkanethiol (as described in Example 3) (483g; 1.0 mole) and 2-butyn-1,4-diol (43.05g; 0.5 mole) were mixed in 500 ml heptane. The system was deoxygenated with nitrogen bubbling below the liquid surface and was then heated to 75° with a blade stirrer rotating at high speed. Azobisisobutyronitrile catalyst (ABN) was added in ten portions of 1.64g each over a 5 hour period. The reaction was continued for a total of 20 hours. During this time the upper part of the flask not covered by the heating mantle was insulated with glass wool to prevent the deposition of the forming product on the walls. The reaction mixture was cooled, with stirring, to allow the product to crystallize. Filtration and drying at 40° and 0.5mm Hg permitted the recovery of 441.7g product (83.7% conversion). From the filtrate and the material removed during the pumping operation 61.2g unreacted thiol were obtained. The overall yield was 96.4%. The product melted over the range 73° - 94°. Gas chromatographic examination showed it to be the dialkyl diol with no trace of the monoaddition product.

EXAMPLES 3-7

Further examples of the free radical addition of 1,1,2,2-tetrahydroperfluoroalkanethiol to 2-butyn-1,4-diol are shown below. Except where indicated, R_f is a mixture of perfluoroalkyl chains C₆F₁₃, C₈F₁₇ and C₁₀F₂₁.

EXAMPLES 3 to 7

Ex.	R _f CH ₂ CH ₂ SH	HOCH ₂ C≡CCH ₂ OH	Solvent	ABN	R _f CH ₂ CH ₂ SCCH ₂ OH		Recovered Thiol	Conversion	% Yield
					Product	Thiol			
3	9.6g ^a ; 0.02m	0.86g; 0.01m	Amsco 46 ^b	328 mg	4.53g	—	—	43.2	—
4	48.0g ^a ; 0.10m	4.2 g; 0.05m	Heptane	1.6g	40.34g	7.44g	—	77.3	92.8
5	96.6g; 0.20m	8.61g; 0.10m	Amsco 46	3.28g	74.8 g	—	—	76.7	—
6	289.8g; 0.60m	25.8g; 0.30m	Heptane	9.84g	254.1 g	43.0 g	—	80.6	94.2
7	289.8g; 0.60m	25.8g; 0.30m	Heptane	9.84g	254.4 g	58.6 g	—	80.6	99.2

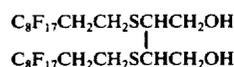
^aC₈F₁₇CH₂CH₂SH used.

^bA hydrocarbon solvent sold by American Mineral Spirits Co. containing 42.4% paraffins, 39.4% naphthenes and 18.2% aromatics.

isobutyronitrile catalyst (ABN) was added in 5 equal portions of 1.32g each, at 25 minute intervals (total catalyst = 6.6g; 0.04 mole or 5 mole % based on thiol). After the second catalyst addition, an exothermic reaction was noted, which took the reaction temperature to 78° for a period of approximately 1 hour. The course of the reaction was followed by periodically removing samples and analysing them by gas-liquid chromatography (GLC). This showed that after 6½ hours no further reaction was occurring. The composition of the crude

EXAMPLE 8

2,3-Bis(1,1,2,2-Tetrahydroperfluorodecylthio)-butane-1,4-diol

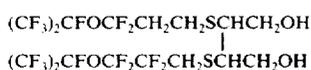


The example shows that the addition may be carried out thermally, without the need for added catalyst.

1,1,2,2-Tetrahydroperfluorodecanethiol (4.8g; 0.01 mole) and 2-butyne-1,4-diol (0.43g; 0.05 mole) were sealed in an ampoule, under nitrogen, with no solvent. The reagents were stirred at 158° for 20 hours during which period a hard, light brown solid formed. Gas chromatographic examination showed this to be 2,3-bis(1,1,2,2-tetrahydroperfluorodecylthio)-butane-1,4-diol. The mono addition product was not formed. The product was purified by crystallization from benzene, and then melted at 105° - 109°. The infrared and nmr data were identical to that obtained for the product of Example 1.

EXAMPLE 9

2,3-Bis(4-Heptafluoroisopropoxy-1,1,2,2-tetrahydroperfluorobutylthio)-butane-1,4-diol



EXAMPLES 11 TO 13

Example	Thiols	Alcohol or Ester	Product
11	2 C ₈ F ₁₇ (CH ₂) ₄ SH	+ HOCH ₂ C≡CCH ₂ OH	C ₈ F ₁₇ (CH ₂) ₄ SCHCH ₂ OH C ₈ F ₁₇ (CH ₂) ₄ SCHCH ₂ OH
12	2 C ₈ F ₁₇ CH ₂ CH ₂ SH	+ CH ₃ CH(OH)C≡CCH(OH)CH ₃	C ₈ F ₁₇ CH ₂ CH ₂ SCHCH(OH)CH ₃ C ₈ F ₁₇ CH ₂ CH ₂ SCHCH(OH)CH ₃
13	2 C ₈ F ₁₇ (CH ₂) ₄ SH	+ H(OCH ₂ CH ₂) _n OCH ₂ C≡CCH ₂ O(CH ₂ CH ₂ O) _n H	C ₈ F ₁₇ CH ₂ CH ₂ SCHCH(OH)CH ₃ C ₈ F ₁₇ (CH ₂) ₄ SCHCH ₂ O(CH ₂ CH ₂ O) _n H C ₈ F ₁₇ (CH ₂) ₄ SCHCH ₂ O(CH ₂ CH ₂ O) _n H

n = 1 average

4-Heptafluoroisopropoxy-1,1,2,2-tetrahydroperfluorobutanethiol (80g; 0.229 mole) was stirred at 74° with 2-butyne-1,4-diol (9.39g; 0.109 mole) under nitrogen. Azobisisobutyronitrile catalyst (1.88g; 0.0114 mole) was added in 5 equal portions at intervals of 25 minutes. After 10 hours GLC indicated that no further reaction was occurring. The crude product was washed with benzene, filtered and dried to give 69.5g product (81.9% of theory). A small sample was further recrystallized and had m.p. 84° - 88°.

The infrared spectrum showed strong O—H stretching frequency at 3,300 cm⁻¹ and characteristic C—F bands at 1,000-1,300 cm⁻¹.

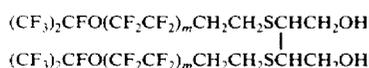
Nmr showed: 2.0-2.6 ppm, CFCH₂ and OH (6H); 2.85 ppm, SCH₂(4H); 3.1 ppm, SCH(2H); and 3.9 ppm, OCH₂(4H).

Equivalent wt: Calc. 389; found 388.

Analysis for C₁₈H₁₆F₂₂O₄S₂ Calculated: C, 27.77; H, 2.07; F, 53.69 Found: C, 28.03; H, 2.03; F, 53.32

EXAMPLE 10

2,3-Bis(Heptafluoroisopropyl-1,1,2,2-tetrahydroperfluoroalkanethio) butane-1,4-diol



m = 3 or 4

ω-Heptafluoroisopropoxy-1,1,2,2-tetrahydroperfluoroalkanethiol [(CF₃)₂CFO(CF₂CF₂)_mCH₂CH₂SH] (consisting of 73% m = 3 homolog and 27% m = 4 homolog) (80g; 0.14 mole) was added to 2-butyne-1,4-diol (5.72g; 0.067 mole), using ABN catalyst (1.15g;

0.007 mole) in the manner described in the previous example. In this case the crude product was purified by passage through a molecular distillation apparatus. This gave 69.7g product and 12.2g recovered thiol. Conversion is thus 83.9% and yield is 99.2% based on starting thiol. The waxy product had a melting point of approximately 37° C. Its nmr and infrared spectra were very similar to those of the preceding example. GLC examination showed that the product was a mixture of three products, formed from the two original thiols. In area % there were: m = 3, 43.3%; m = 3, 40.9%; m = 4, 15.80%.

Analysis: Calculated: on the basis of wt. % = area % C, 26.36; H, 1.29; F, 62.07 Found: C, 27.37; H, 1.39; F, 61.19

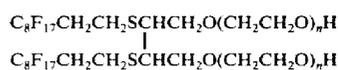
EXAMPLES 11 TO 13:

Addition of available thiols to commercial acetylenic alcohols and esters is illustrated by Examples 11 to 13.

In each case a free radical catalyzed addition of 2 moles of thiol to 1 mole acetylenic alcohol is involved. The experimental procedure is as described in Example 2a.

EXAMPLE 14

2,3-Bis(1,1,2,2-Tetrahydroperfluorodecylthio)butane-1,4-di(hydroxy ethyl ether)



n = average 1

In a glass ampoule, 1,1,2,2-tetrahydroperfluorodecanethiol (15.4g; 0.033 mole) and 2-butyne-1,4-hydroxyethyl ether* (2.61g; 0.015 mole) were shaken and heated at 75° with 492 mg ABN for 18 hours in 20 ml heptane. A waxy product was obtained which after removal of excess thiol, melted in the range of 26° - 48°. Infrared examination confirmed the assigned structure, showing O-H stretching frequency at 3405 cm⁻¹. Nmr showed signals at 2.2 - 3.2 ppm SCH₂CH₂R_f and 3.2 - 4.2 ppm —CHO(CH₂CH₂O)_nH with the correct integrals.

* A commercial product H(OCH₂CH₂)_nOCH₂C≡CCH₂O(CH₂CH₂O)_nH, with n = 1 average, but actually being a mixture of at least five distinct compounds.

Elemental analysis: Calculated for C₂₈H₂₄F₃₄O₄S₂ (average n = 1) C 29.64; 2.13; F 56.9 Found: C 30.04; H 2.25; F 55.8

EXAMPLE 15

2,3-Bis(1,1,2,2-Tetrahydroperfluorodecylthio)butyl-1,4-diacetate

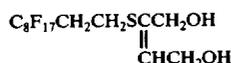


In a similar manner as Example 14, 1,1,2,2-tetrahydroperfluorodecanethiol (15.84g; 0.033 mole) 2-butyne-1,4-diacetate (2.55g; 0.015 mole) and 492 mg azobisisobutyronitrile were heated at 75° for 19 hours to give 12.3 g (67%) product boiling at 185° at 0.1 mm Hg. infrared analysis (C=O stretching frequency at 1750 cm⁻¹ and the absence of all O-H frequency bands) and nmr examination confirmed the structure. Nmr showed signals at 2.3 - 3.2 ppm (8H) SCH₂CH₂; 3.45 ppm (2H) SCH; and 4.38 ppm (4H) OCH₂. The methyl protons resonated at 2.05 ppm.

Elemental Analysis: Calculated for C₂₈H₂₀F₃₄O₄S₂: C, 29.75 H, 1.78 F, 57.14 Found: C, 29.83 H, 1.78 F, 56.59

EXAMPLE 16

2-(1,1,2,2-Tetrahydroperfluorodecylthio)-2-butene-1,4-diol



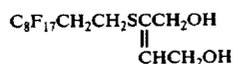
1,1,2,2-Tetrahydroperfluorodecanethiol (24g; 0.05 mole) was added slowly to a mixture of 2-butyne-1,4-diol (6.5g; 0.076 mole) in heptane, containing 820 mg ABN catalyst. This procedure gave a product enriched in the butenediol desired but also containing some of the diadduct (butanediol). The monoadduct butenediol was obtained in a pure state by sublimation at 150° and 0.7 mm Hg.

M.P. 87° - 89°. Nmr showed peaks at 2.2 - 3.2 ppm (4H) CH₂CH₂S; 3.8 ppm (2H) OH, 4.22 ppm (2H) S—C—CH₂O; 6.24 ppm (1H) = CH. The yield was 26%.

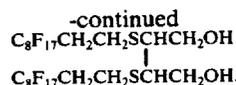
Elemental Analysis Calculated for C₁₄H₁₁F₁₇O₂S: C, 29.69 H, 1.96 F, 57.03 Found: C, 29.49 H, 1.89 F, 56.71

EXAMPLES 17 - 29

The following examples illustrates the wide variety of solvents which may be used in the reaction. All reactions were carried out with 1,1,2,2-tetrahydroperfluorodecanethiol (5.28g; 0.011 mole), 2-butyne-1,4-diol (0.43 g; 0.005 mole) and 164 mg azobisisobutyronitrile. A reaction time of 18 hours at 76° was uniform for each example. Product analysis was made by gas chromatography. Since an excess of thiol was used, the results are given below in two sections. The first shows the thiol present in relation to the mono- and di-adducts and is thus an indication of the suitability of the solvent. The second section shows the relative amounts of mono-adduct to di-adduct, without regard to the thiol present. In each case the mono-adduct is



and the di-adduct is



The results show that an inert, non-polar reaction medium, typically n-heptane, leads to maximum conversion of thiol and greatest production of di-adduct

EXAMPLES 17 to 29

Example	Solvent (10 ml)	G. C. Analysis (area %)				
		Thiol	Mono.	Di.	Mono	Di.
17	heptane	12.4	0.8	86.6	0.9	99.1
18	acetone***	55.0	17.4	27.6	38.7	61.3
19	MEK	51.2	18.9	29.9	38.8	61.2
20	benzene	24.7	23.0	52.3	26.9	73.1
21	toluene	23.4	24.4	52.2	31.8	68.2
22	xylene	24.2	21.5	54.3	28.4	71.6
23	perchloro-ethylene* carbon tetrachloride**	29.2	0	3.9	—	—
24	ethylene dichloride	18.7	3.8	44.9	7.8	92.2
25	ethyl acetate	48.3	22.3	29.4	43.1	56.9
26	t-butyl alcohol	47.8	9.2	43.0	17.6	82.2
27	methyl cellosolve	43.1	26.1	30.8	45.9	54.1
28	isopropyl alcohol	39.0	19.3	41.7	31.6	68.0
29	isopropyl alcohol	44.7	27.1	28.2	49.0	51.0

*principal products were disulfide (C₈F₁₇CH₂CH₂S)₂, accounting for 28.2% and three unidentified materials (total 38.7%)

**disulfide (32.6%) was major impurity

***reaction temperature 60°

EXAMPLES 30 to 36

Various free radical catalysts, in addition to ultraviolet irradiation, may be used to initiate the addition reaction. Below shows the effect of several different chemical initiators. Their effectiveness is judged by the amount of thiol consumed. In each reaction 1,1,2,2-tetrahydroperfluorodecanethiol (4.8g; 0.01 mole) and 2-butyne-1,4-diol were heated with the designated catalyst (10 mole % based on thiol). Heptane was used as a solvent except as indicated.

Example	Catalyst	Reaction		Thiol Consumed
		Temp °C	Time Hrs.	
30	benzoyl peroxide	90	18	45
31	lauroyl peroxide	85	18	42
32	azo bisobutyronitrile	75	18	78
33	2-t-butyl azobisisobutyronitrile	100*	17	75
34	1-t-butyl azo-1-cyano-cyclohexane	117*	17	76
35	2,5-dimethyl-2,5-di(t-butylperoxy) hexane	130**	20	28
36	di-t-butyl peroxide	140**	20	33

*methyl isobutylketone solvent

**o-xylene solvent

All peroxides gave poor conversions of thiol to di-adduct and also gave rise to considerable amounts of unidentified by-products. Thus the actual conversion of thiol to di-adduct in these cases is much lower than the actual thiol consumption.

EXAMPLES 37 to 45

Other examples of the radical catalyzed addition of R_f-thiol to commercial acetylenic alcohols and eters, using reaction conditions as shown in Example 2a are listed below.

Examples 37 to 45 illustrate additional combinations of R_f-thiols with acetylenic diols and esters. The reaction conditions are those of Example 2a.

Examples 37 to 45

Example	Thiol	Alcohol or Ester	Product
37	2 C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SH	+ HOCH ₂ C≡CCH ₂ OH →	C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SCHCH ₂ OH
38	2 C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SH	+ H(OCH ₂ CH ₂) _n OCH ₂ C≡CCH ₂ O(CH ₂ CH ₂ O) _n H →	C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SCHCH ₂ OH C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H
39	2 C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SH	+ CH ₃ COOCH ₂ C≡CCH ₂ OCOCH ₃ →	C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H n = 1 average
40	2 C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SH	+ HOCH ₂ C≡CCH ₂ OH →	C ₈ F ₁₇ CH ₂ CH ₂ SCH ₂ CH ₂ CH ₂ SCHCH ₂ OCOCH ₃ C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SCHCH ₂ OH
41	2 C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SH	+ H(OCH ₂ CH ₂) _n OCH ₂ C≡CCH ₂ O(CH ₂ CH ₂ O) _n H →	C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SCHCH ₂ OH C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H
42	2 C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SH	+ CH ₃ COOCH ₂ C≡CCH ₂ OCOCH ₃ →	C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H n = 1 average
43	2 C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SH	+ HOCH ₂ C≡CCH ₂ OH →	C ₈ F ₁₇ CH ₂ CH ₂ OCH ₂ CH ₂ CH ₂ SCHCH ₂ OCOCH ₃ C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SCHCH ₂ OH
44	2 C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SH	+ H(OCH ₂ CH ₂) _n OCH ₂ C≡CCH ₂ O(CH ₂ CH ₂ O) _n H →	C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SCHCH ₂ OH C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H
45	2 C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SH	+ CH ₃ COOCH ₂ C≡CCH ₂ OCOCH ₃ →	C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SCHCH ₂ O(CH ₂ CH ₂ O) _n H C ₈ F ₁₇ CH ₂ CH ₂ N(CH ₃)CH ₂ CH ₂ SCHCH ₂ OCOCH ₃

Examples 46 to 63 illustrate the conversion of the perfluoroalkylthioglycols described herein the fluorine-containing urethane compositions.

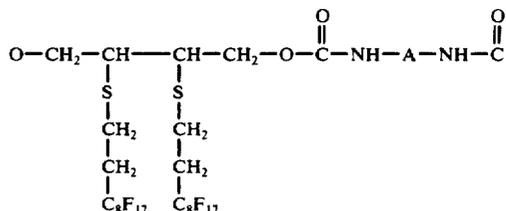
EXAMPLE 46

The diol of Example 1 (7.85 grams; 0.0075 mole) and Tonco 70 (a commercial mono-isocyanate containing 70% octadecyl isocyanate and 30% hexadecyl isocyanate) 4.31 grams; 0.05 mole) were dissolved in 20 ml urethane grade methyl ethyl ketone in a sealed reaction vessel. As a catalyst, 456 mg of a 1% solution of dibutyltindilaurate (7.5 × 10⁻⁶ moles catalyst) in MEK was added and the reactor was heated at 75°, with agitation, for 18 hours, when infrared examination showed all —NCO functionality to be absent (no stretching vibration at 2275 cm⁻¹). 11.3 grams of urethane was obtained as an amber wax by evaporation of the solvent. The

5

10

15



where A is the residue obtained from the indicated diisocyanate.

The R_F-glycol and the diisocyanate were dissolved in about 20 ml urethane grade methyl ethyl ketone in a sealed reaction vessel. The indicated amount of catalyst was added and the reactor heated for 17 hours at 73° C with agitation. The results are summarized below.

Ex.	Weight	Moles	Isocyanate*	Weight	Mole	CATALYST** Wt. g 1% Soln.	Moles	Weight of Product (grams)	Elemental Calcd.	Anal. Found	γc*** dynes/cm
48	8.37	0.008	DDI	4.80	0.008	485 mg	8 × 10 ⁻⁶	6.0	C 45.53 H 5.42 N 1.71 F 39.50	45.98 5.36 1.81 38.83	12.66
49	10.46	0.010	LDIM	2.12	0.010	607 mg	1 × 10 ⁻⁵	10.0	C 31.49 H 2.24 F 51.32	31.85 2.37 50.77	11.88
50	11.51	0.011	HDI	1.85	0.011	688 mg	1.1 × 10 ⁻⁵	10.4	C 31.64 H 2.32 F 53.18	31.54 2.21 52.21	11.50
51	10.46	0.010	TMDI	2.10	0.010	607 mg	1 × 10 ⁻⁵	10	C 33.45 H 2.73 F 51.40	33.27 2.80 51.41	12.95
52	11.51	0.011	TDI	1.91	0.011	688 mg	1.1 × 10 ⁻⁵	10.2	C 32.47 H 1.82 F 52.92	32.67 1.85 52.74	12.66

*DDI = dimeracid derived isocyanate - Quaker Oats Company

LDIM = Lysinediisocyanate methyl ester - Merck and Company

TDI = toluene 2,4-diisocyanate

**catalyst dibutyltindilamate, 1% in MEK

***critical surface tension for wetting

product melted at 73° to 88°. The infrared spectrum showed N—H str. at 3335 cm⁻¹ and C=O str. at 1694 cm⁻¹.

Elemental Analysis: Calc'd: C, 45.06; H, 5.45; N, 1.73; F, 39.86 Found: C, 45.00; H, 5.41; N, 1.74; F, 39.69

EXAMPLE 47

When the diol of Example 1 (7.85 grams; 0.0075 mole) and Desmodur RF [a commercial thiophosphoryl tris (4-phenylisocyanate)] (2.09 grams; 0.005 moles) are reacted according to the conditions of Example 46 there are obtained 8.0 grams of urethane product as a hard granular material.

Low molecular weight urethane compositions such as are described in Examples 46 and 47 are useful as coatings on vinyl surfaces to render the same soil repellent. The urethane composition can be applied from MEK solution to vinyl sheeting and the treated material resists soiling according to a standard test, in contrast to an untreated sample.

EXAMPLE 48 to 52

2,3-bis (1,1,2,2-tetrahydroperfluorodecylthio) butane-1,4-diol (the diol of Example 1) was converted by reaction with equimolar amounts of a diisocyanate to a high molecular weight urethane composition characterized by the presence of a segment of formula:

40

EXAMPLE 53

A hydroxy terminated R_F-containing prepolymer was prepared as follows:

2,3-Bis(1,1,2,2-tetrahydroperfluorodecylthio)butane-1,4-diol (the diol of Example 1) (20 g; 0.0191 mole) was mixed with lysine diisocyanate methyl ester (2.7 g; 0.0127 mole) in 20 g. methylethyl ketone. Dibutyltindilaurate was added (23 mg; 3.82 × 10⁻⁵ mole) to the resulting solution and the reaction vessel was heated to 75° with agitation until all isocyanate had reacted, as shown by the disappearance of the N=C=O band in the infrared. The solution was divided into two equal parts. One was used for Example 54. The other was poured into cold heptane to precipitate the urethane product. After drying this portion weighed 21.0 g. Infrared showed peaks at 3480 cm⁻¹ (O—H str.); 3340 cm⁻¹ (N—H str.) and 1715 cm⁻¹ (C=O str.; ester and urethane).

Elemental Analysis: Calc'd for C₉₀H₇₂F₁₀₂N₄O₁₄S₆: C, 30.33; H, 2.04; N, 1.57; F, 54.38 Found: C, 30.61; H, 2.00; N, 1.67; F, 53.96

EXAMPLE 54

The hydroxy-terminated R_F-containing prepolymer was converted into a urethane composition by reaction with additional diisocyanate and the reaction product capped by reaction with a monoalcohol.

The prepolymer of Example 53 was treated by 75° with further amounts of lysine diisocyanate (1.35 g;

0.0064 mole) to cap the free OH groups and the urethane was terminated by the addition of 2,3-bis(1,1,2,2-tetrahydroperfluorodecylthio) propan-1-ol (6.5 g; 0.0064 mole). Reaction was judged to be complete when no isocyanate peaks were visible in the infrared. The product was precipitated by pouring the MEK solution slowly into chilled heptane. After drying the final urethane weighed 28.9 g, and had a rubbery consistency. No OH stretching frequencies were visible in the infrared, but N—H stretching frequency was present at 3335 cm^{-1} and C=O (ester and urethane) was a broad band centered at 1715 cm^{-1} .

Elemental Analysis for $\text{C}_{154}\text{H}_{124}\text{F}_{170}\text{N}_8\text{O}_{24}\text{S}_{10}$ Calculated: C, 30.72; H, 2.08; N, 1.86; F, 53.64 Found: C, 30.75; H, 2.10; N, 1.94; F, 52.95

EXAMPLE 55

This example illustrates the formation of diisocyanate-terminated R_f -containing intermediate and the conversion thereof to a high and low (relative) molecular weight urethane compositions.

A. High molecular weight

2,3-Bis(1,1,2,2-tetrahydroperfluorodecylthio)butane-1,4-diol (the diol of Example 1) (57.33 g; 0.055 mole) was dissolved in 150 g methylethyl ketone. Lysine diisocyanate methyl ester (5.83 g; 0.0275 mole) was added, followed by 3.46 g of a 1% solution of dibutyl tin dilaurate as catalyst. The solution was heated under reflux and stirred in a nitrogen atmosphere for 2½ hours. Then dimer acid derived diisocyanate (DDI, available from The Quaker Oats Company) (33.0 g; 0.055 mole) was added and heating and stirring were continued for a further 3 hours. To complete the urethane formation the isocyanate capped intermediate was divided into two equal parts. The first was treated with lysine diisocyanate methyl ester (2.77 g; 0.013 mole) and N-methyl diethanolamine (3.11 g; 0.027 mole), to give a material which was purified by evaporation of the solvent followed by freeze drying from benzene. An infrared spectrum of the material showed N—H str. at 3336 cm^{-1} and a broad carbonyl band (C=) str. with a main peak at 1690 cm^{-1} , due to the ester and urethane linkages. The material was only sparingly soluble in methanol.

Elemental Analysis for $\text{C}_{152}\text{H}_{226}\text{F}_{68}\text{N}_{10}\text{O}_{20}\text{S}_4$ Calculated: C, 46.4; H, 5.8; F, 32.8 Found: C, 46.5; H, 5.6; F, 33.8 Critical surface tension for wetting, $\gamma_c = 11.32$ dynes/cm.

B. Low molecular weight

The second half of the isocyanate capped prepolymer was treated with lysine diisocyanate methyl ester (2.77 g; 0.013 mole) and N-methyldiethanolamine (3.67 g; 0.031 mole). The excess termination diol acts as a chain terminator and gives a lower molecular weight polyurethane. By freeze drying, a quantitative yield of polyurethane was obtained. The infrared spectrum and elemental analyses were similar to those of part A. The principal difference was that the low molecular weight urethane was very soluble in methanol, and could only be recovered in good yield by freeze drying from benzene.

Critical surface tension for wetting, $\gamma_c = 12.37$ dynes/cm.

EXAMPLE 56

A hydroxy-terminated R_f -containing prepolymer was prepared as follows:

Methyl ethyl ketone (600 g) was charged to a 2 l. flask fitted with a stirrer, thermometer, nitrogen inlet and a condenser protected with a drying tube. 2,3-Bis-

(1,1,2,2-tetrahydroperfluoroalkylthio)butane-1,4-diol (600 g; 0.571 mole)* was added together with a 1:1 mixture of 2,2,4-trimethylhexamethylene diisocyanate and 2,4,4-trimethylhexamethylene diisocyanate (80.16 g; 0.381 mole). All reagents were rinsed in with an additional 50 g MEK. The solution was heated to boiling and 50 g solvent was removed by distillation to effect azeotropic drying of all materials. Then dibutyl-tindilaurate (0.692 g; 1.14×10^{-3} mole; 2 mole % based on diol) was added as a catalyst and the solution was heated under reflux for six hours, when the reaction was judged to be complete by the absence of the N=C=O infrared band at 2270 cm^{-1} . The solution was cooled to room temperature (25°) and diluted with MEK to a total of 2042 g (33½% solids). A portion of the above material was taken to dryness. A quantitative recovery of a resinous material was obtained. Elemental analysis showed 52.8%F (theory: 53.4%F). Infrared bands at 3460 cm^{-1} (O—H str.), 3340 cm^{-1} (N—H str.) and 1705 cm^{-1} (C=) str. confirmed the structure of the hydroxy-terminated urethane prepolymer.

*The diol has the formula

$$\begin{array}{c} R_f\text{CH}_2\text{CH}_2\text{SCHCH}_2\text{OH} \\ | \\ R_f\text{CH}_2\text{CH}_2\text{SCHCH}_2\text{OH} \end{array}$$

where R_f is a mixture of prefluoroalkyl chains consisting of C_6F_{13} , C_8F_{17} and $\text{C}_{10}\text{F}_{21}$. The diol is described in Example 2.

EXAMPLE 57

The hydroxy-terminated prepolymer of Example 56 (53.7 g solution, 17.9 solids) was treated further at 75° with dimer acid derived diisocyanate (6.0 g; 0.01 mole) (DDI, Quaker Oats Company) for two hours, then the urethane chain was completed by the addition of trimethylhexamethylene diisocyanate (2,2,4 and 2,4,4 isomer mixture) (1.05 g; 0.005 mole) and N-methyldiethanolamine (1.19 g; 0.01 mole). Reaction was complete in three hours, as shown by the disappearance of the N=C=O band (2270 cm^{-1}) in the infrared spectrum. A sample taken to dryness gave a quantitative yield of an off-white powder containing 35.8%F (theory 36.6%F). For application to textile fabrics the polyurethane was applied either from solvent (MEK solution) or as an aqueous emulsion. The latter was made by first quaternizing the tertiary nitrogen atoms with glacial acetic acid and then pouring the MEK solution into a sufficient volume of water to give a clear emulsion.

EXAMPLE 58

The prepolymer of Example 56 (53.7 g solution; 17.9 g solids) was treated as in Example 57 with dimer acid derived isocyanate (6.0 g; 0.01 mole) (DDI, Quaker Oats Company) for 2 hours at 75° followed by further reaction with N-methyldiethanolamine (3.57 g; 0.03 mole) and dimer acid derived isocyanate (15.0 g; 0.025 mole) (DDI). Reaction was judged to be complete in 3 hours. An aliquot of the polyurethane solution was taken to dryness to yield a quantitative amount of off-white powder, containing 23.0%F (theory 22.4%). Application to fabrics was made either as a solvent material or as a self-emulsifiable quaternized polyurethane as described in Example 57.

Another alternative is for a conventional hydroxyl terminated polymer, as previously exemplified, to be co-applied, from solvent, with a fiber-reactive resin, such as a polymethylolmelamine, which will react, on curing, with the —OH groups of both the fiber and the polyurethane.

EXAMPLE 63

Methyl ethyl ketone (600 g) is charged to a 2 l. flask fitted with a stirrer, thermometer, nitrogen inlet and a condenser protected with a drying tube. 2,3-bis-(1,1,2,2-tetrahydroperfluoroalkylthio)butane 1,4-diol (600 g; 0.571 mole) the diol of Example 2, is added together with a 1:1 mixture of 2,2,4-trimethylhexamethylene diisocyanate and 2,4,4-trimethylhexamethylenediisocyanate (80.16 g; 0.381 mole). All reagents are rinsed in with an additional 50 g MEK. The solution is heated to boiling and 50 g solvent are removed by distillation to effect azeotropic drying of all materials. Then dibutyltindilaurate (0.692 g; 1.14×10^{-3} mole; 2 mole % based on diol) is added as a catalyst and the solution heated under reflux for six hours. At the end of this time the reaction is judged to be complete by the absence of the $N=C=O$ infrared band at 2270 cm^{-1} . A further 800 ml of MEK are added and the hydroxyl terminated prepolymer treated further with dimer acid derived diisocyanate (228.6 g; 0.381 mole) (DDI) for two hours. The urethane chain is completed by the addition of further dimer acid derived diisocyanate (457.6 g; 0.762 mole) (DDI) and 1,4-butanediol (68.5 g; 0.762 mole).

The presence of —NCO bands in the final product is shown by infrared adsorption (2270 cm^{-1}). Addition of 1450 ml MEK gave a product containing 33½% solids. This product is applied to fabrics by application from solvent by diluting the concentrate with 1,1,1-trichloroethane such that the treating bath contains approximately 0.2%F. Fabrics so treated typically exhibit an oil repellency of 6 and a water spray rating of 80.

EXAMPLE 64

This example illustrates the conversion of a perfluoroalkylalkylene iodide to the corresponding thiol by reaction with thiourea.

In a 1 liter flask is placed 100 g (0.138 mole) of $C_{11}F_{23}CH_2CH_2I$, 12.6 (0.166 mole) of thiourea and 100 ml of anhydrous ethanol and the mixture is refluxed for 5 hours. Then about 50 ml of the ethanol is stripped off under vacuum and 400 ml H_2O and 11.04 g (0.138 mole) of 50% aqueous NaOH are added and the reaction mixture is boiled.

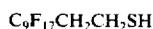
The mercaptan, $C_{11}F_{23}CH_2CH_2SH$, is collected in a Dean-Stark trap as a lower layer in good yield.

EXAMPLE 65

This example illustrates two alternate synthetic methods for preparing the thiol $R_f - R_1 - SH$

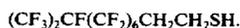
A. Reaction of $R_f - CH = CH_2$ with H_2S .

The olefin $C_9F_{19}CH = CH_2$ is reacted with H_2S at $+5^\circ\text{C}$ at 200 PSIG H_2S , the mole ratio of H_2S to olefin being about 30:1 in a water jacketed quartz tube irradiated with the ultraviolet light furnished by two 36 inch germicidal lamps under static conditions. The major product is:



B. Reaction of $R_fCH_2CH_2I$ with thiourea followed by hydrolysis.

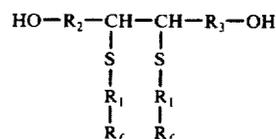
In a 5 liter round bottom flask equipped with a water cooled condenser, stirrer and heating mantle is placed 624 g (1.0 mole) of $CF_3)_2CF(CF_2)_6CH_2CH_2I$, 114 g thiourea (1.5 mole) and 3 liters of absolute ethanol. The reaction mixture is heated at reflux for 26 hours. Ethanol is then removed while adding water to maintain constant volume. 200 ml of 1M NaOH is then added and the solution co-distilled with water into a phase separator. The aqueous phase is returned to the reaction vessel. Further distillation gives the pure mercaptan



What we claim is:

1. A urethane derived from

- an organic isocyanate which is an aromatic isocyanate or an alkyl isocyanate of 1 to 36 carbon atoms and
- an R_f glycol of formula

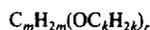


where

R_f is perfluoroalkyl of 1 to 18 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms;

R_1 is branched or straight chain alkylene of 1 to 12 carbon atoms, alkylenethioalkylene of 2 to 12 carbon atoms, alkyleneoxyalkylene of 2 to 12 carbon atoms, or alkyleneiminoalkylene of 2 to 12 carbon atoms where the nitrogen atom contains as a third substituent, hydrogen or alkyl of 1 to 6 carbon atoms;

R_2 and R_3 independently are straight or branched chain alkylene of 1 to 12 carbon atoms, said alkylene substituted by 1 or 2 of phenyl or cyclohexyl; or R_2 and R_3 are a group of formula



where

m is an integer from 1 to 12,

k is an integer from 2 to 6,

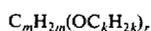
r is an integer from 1 to 40.

2. A urethane of claim 1, in which

R_f is perfluoroalkyl of 6 to 12 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms;

R_1 is branched or straight chain alkylene of 2 to 8 carbon atoms, alkylenethioalkylene of 2 to 8 carbon atoms, alkyleneoxyalkylene of 2 to 8 carbon atoms or alkyleneiminoalkylene of 2 to 8 carbon atoms and where the nitrogen atoms contains hydrogen or methyl as a third substituent;

R_2 and R_3 are each independently a straight or branched chain alkylene of 1 to 4 carbon atoms or a group of formula



where

m is an integer from 1 to 4,

k is an integer from 2 to 4,

r is an integer from 1 to 20.

3. A urethane of claim 1, in which

R_f is perfluoroalkyl of 6 to 12 carbon atoms,

R_1 is alkylene of 2 to 4 carbon atoms, and

R_2 and R_3 are each alkylene of 1 or 2 carbon atoms.

4. A urethane of claim 1, in which the organic isocyanate is an aromatic isocyanate or an alkyl isocyanate of 1 to 16 carbon atoms.

5. A urethane of claim 1, in which the organic isocyanate is an alkylene diisocyanate of 2 to 16 carbon atoms, or an aromatic diisocyanate of 6 to 30 carbon atoms.

6. A urethane of claim 5, in which the aromatic diisocyanate has the formula



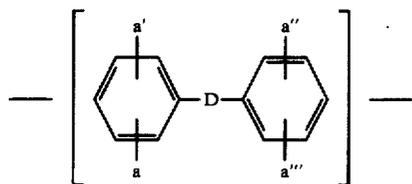
where

A is phenylene that is unsubstituted or substituted by one or two of alkyl of 1 to 4 carbon atoms, alkoxy of 1 to 4 carbon atoms, amino, chloro, bromo and nitro;

naphthylene that is unsubstituted or substituted by one or two of alkyl of 1 to 4 carbon atoms, chloro, bromo and nitro;

or where

A is a group of formula

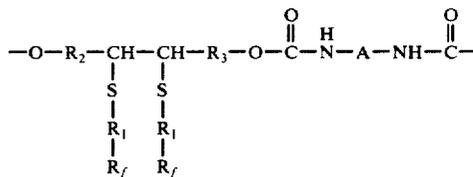


where

D is a direct bond, oxygen, methylene or ethylene and

a , a' , a'' and a''' each independently is hydrogen, alkyl of 1 to 4 carbon atoms, alkoxy of 1 to 4 carbon atoms, chloro or bromo.

7. A urethane composition containing recurring units of the formula



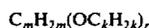
5 where

A is alkylene of 2 to 16 carbon atoms or arylene,

R_f is perfluoroalkyl of 1 to 18 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms,

15 R_1 is branched or straight chain alkylene of 1 to 12 carbon atoms, alkylthioalkylene of 2 to 12 carbon atoms, alkyleneoxyalkylene of 2 to 12 carbon atoms, or alkyleneiminoalkylene of 2 to 12 carbon atoms where the nitrogen atom contains as a third substituent, hydrogen or alkyl of 1 to 6 carbon atoms,

R_2 and R_3 each independently is straight or branched chain alkylene of 1 to 12 carbon atoms; straight or branched chain alkylene of 1 to 12 carbon atoms substituted by one or two of phenyl or cyclohexyl; or R_2 and R_3 are a group of the formula



25 where

m is an integer from 1 to 12,

k is an integer from 2 to 6,

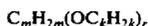
r is an integer from 1 to 40.

8. A urethane composition according to claim 7, in which

35 R_f is perfluoroalkyl of 6 to 12 carbon atoms or said perfluoroalkyl substituted by perfluoroalkoxy of 2 to 6 carbon atoms,

R_1 is branched or straight chain alkylene of 2 to 8 carbon atoms, alkylthioalkylene of 2 to 8 carbon atoms, alkyleneoxyalkylene of 2 to 8 carbon atoms or alkyleneiminoalkylene of 2 to 8 carbon atoms and where the nitrogen atom contains hydrogen or methyl as a third substituent;

45 R_2 and R_3 are each independently straight or branched chain alkylene of 1 to 4 carbon atoms or a group of formula



50 where

m is an integer from 1 to 4,

k is an integer from 2 to 4,

r is an integer from 1 to 20.

9. A urethane composition according to claim 7, in which

R_f is perfluoroalkyl of 6 to 12 carbon atoms,

R_1 is alkylene of 2 to 4 carbon atoms,

R_2 and R_3 are both alkylene of 1 or 2 carbon atoms.

* * * * *

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